Effects of Organic Zinc and Organic Manganese on Production Performance, Egg Quality, Antioxidant Capacity, and Immune Function in Laying Breeder Hens: Postprint

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Abstract

This experiment was conducted to investigate the effects of dietary supplementation with organic zinc and manganese on the production performance, egg quality, antioxidant capacity, and immune function of laying breeder hens. A total of 576 healthy 23-week-old Hy-Line Brown D-line grandparent laying breeder hens with similar body weight were selected and randomly allocated to 3 groups, with 12 replicates per group and 16 hens per replicate. The control group (Group A) received a basal diet supplemented with 80 mg/kg zinc sulfate and manganese sulfate; the equal replacement group (Group B) had 40 mg/kg of the zinc sulfate and manganese sulfate in the control diet replaced with 40 mg/kg organic zinc and organic manganese, respectively; the extra supplementation group (Group C) was fed the control diet with an additional 40 mg/kg organic zinc and organic manganese. The experimental period lasted 32 weeks. The results showed: 1) At week 32 and during weeks 1-32, the average egg weight of hens in Group B was significantly higher than that of the control group ($P<0.05$); at week 24, the laying rate of Group C was significantly higher than that of the control group ($P<0.05$); the broken egg rate of Group C was significantly lower than that of Group B ($P<0.05$) and extremely significantly lower than that of the control group ($P<0.01$). 2) At week 16, the egg shape index of Group B was significantly higher than that of the other groups ($P<0.05$), and the manganese content in egg yolk of Group C was significantly higher than that of the control group ($P<0.05$); at week 32, the eggshell lightness of Group C was significantly higher than that of Group B ($P<0.05$), the eggshell redness of Groups B and C was extremely significantly higher than that of the control group ($P<0.01$), and the manganese content in egg yolk of Group B was extremely significantly higher than that of the other groups ($P<0.01$). 3) Dietary supplementation with organic zinc and manganese had no significant effects on the activities of blood total superoxide dismutase (T-SOD), manganese superoxide dismutase (Mn-SOD), and copper-zinc superoxide dismutase (Cu/Zn-SOD), T lymphocyte subset proportions (CD4, CD8, and CD4/CD8), or cutaneous basophil hypersensitivity (CBH) response in laying breeder hens ($P>0.05$). In conclusion, dietary supplementation with organic zinc and manganese can increase the average egg weight and laying rate, reduce the broken egg rate, increase eggshell strength, improve egg quality, and enhance manganese deposition in egg yolk of laying breeder hens. Under the conditions of this experiment, equal replacement of inorganic zinc and manganese with organic zinc and manganese yielded the best results.

Full Text

Effects of Organic Zinc and Organic Manganese on Performance, Egg Quality, Antioxidant Capacity, and Immune Function of Laying Breeder Hens

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Abstract

This study was conducted to evaluate the effects of dietary organic zinc and organic manganese on performance, egg quality, antioxidant capacity, and immune function of laying breeder hens. Five hundred seventy-six healthy Hy-Line Brown D strain grandparent laying breeder hens at 23 weeks of age with similar body weight were randomly allocated to 3 groups with 12 replicates per group and 16 hens per replicate. The control group (Group A) received a basal diet supplemented with 80 mg/kg zinc sulfate and 80 mg/kg manganese sulfate. The equivalent replacement group (Group B) received the basal diet where 40 mg/kg organic zinc and 40 mg/kg organic manganese replaced 40 mg/kg of the inorganic zinc and manganese sulfates, respectively. The extra supplementation group (Group C) received the control diet with an additional 40 mg/kg organic zinc and 40 mg/kg organic manganese. The experiment lasted for 32 weeks. The results showed: 1) At week 32 and during weeks 1-32, average egg weight in Group B was significantly higher than in the control group ($P<0.05$). At week 24, laying rate in Group C was significantly higher than in the control group ($P<0.05$). Broken egg rate in Group C was significantly lower than in Group B ($P<0.05$) and extremely significantly lower than in the control group ($P<0.01$). 2) At week 16, egg shape index in Group B was significantly higher than in the other groups ($P<0.05$), and yolk manganese content in Group C was significantly higher than in the control group ($P<0.05$). At week 32, eggshell lightness in Group C was significantly higher than in Group B ($P<0.05$), while eggshell redness in Groups B and C was extremely significantly higher than in the control group (P<0.01). Yolk manganese content in Group B was extremely significantly higher than in the other groups (P<0.01). 3) Dietary organic zinc and organic manganese had no significant effects on blood total superoxide dismutase (T-SOD), manganese superoxide dismutase (Mn-SOD), or copper-zinc superoxide dismutase (Cu/Zn-SOD) activities, T lymphocyte subset proportions (CD4, CD8, and CD4/CD8 ratio), or cutaneous basophil hypersensitivity (CBH) reaction (P>0.05). In conclusion, dietary organic zinc and organic manganese can increase average egg weight and laying rate, decrease broken egg rate, improve eggshell strength and egg quality, and increase manganese deposition in egg yolk. Under the conditions of this experiment, equivalent replacement of inorganic zinc and manganese with organic forms produced the optimal effects.

Keywords: organic zinc; organic manganese; laying breeder hens; performance; egg quality; antioxidant capacity; immune function

Trace elements are essential nutrients for livestock and poultry, directly or indirectly participating in physiological and biochemical processes and playing important roles in maintaining animal growth and health. Insufficient dietary zinc and manganese can adversely affect reproductive performance and embryonic development in breeding hens, causing decreased egg production, reduced eggshell strength, lower fertility and hatchability, abnormal embryonic bone development, poor feathering, and dermatitis. The composition and content of trace elements in conventional feedstuffs vary considerably due to differences in geographical environment, climate, and crop yield, necessitating supplementation in practical production. Traditionally, trace elements are added to diets primarily as inorganic salts, which have low bioavailability and can undergo oxidation reactions that destroy vitamins in feed additives. Organic trace elements chelated with amino acids or proteins offer advantages such as high absorption rates and biological efficacy, increasingly replacing inorganic forms in feed. This study investigated the effects of dietary organic zinc and organic manganese on performance, egg quality, antioxidant capacity, and immune function of laying breeder hens to provide reference for their application in breeding hen production.

1.1 Experimental Materials

Inorganic zinc was provided as zinc sulfate monohydrate containing 34.8% zinc. Inorganic manganese was provided as manganese sulfate monohydrate containing 31.8% manganese. Organic zinc and organic manganese were amino acid chelates produced from hydrolyzed plant protein sources, containing 12% zinc and 8% manganese, respectively, both products of Zinpro Corporation (USA).

1.2 Experimental Diet and Design

A basal diet for laying breeder hens during peak production was formulated according to NRC (1994) standards. The composition and nutrient levels of the basal diet are presented in Table 1 . Five hundred seventy-six healthy Hy-Line Brown D strain grandparent laying breeder hens at 23 weeks of age with similar body weight were randomly divided into 3 groups with 12 replicates per group. Each replicate consisted of 8 consecutive cages with 2 hens per cage. A completely randomized experimental design was employed. The control group (Group A) received the basal diet supplemented with 80 mg/kg zinc sulfate and 80 mg/kg manganese sulfate. Group B received the basal diet where 40 mg/kg organic zinc and 40 mg/kg organic manganese replaced 40 mg/kg of the inorganic zinc and manganese sulfates, respectively. Group C received the control diet with an additional 40 mg/kg organic zinc and 40 mg/kg organic manganese. The measured dietary zinc concentrations were 118.29, 109.43, and 158.61 mg/kg, and manganese concentrations were 109.72, 103.40, and 147.85 mg/kg for Groups A, B, and C, respectively.

Table 1 Composition and nutrient levels of the basal diet (air-dry basis)

Item	Content
Corn	63.80
Soybean meal	21.50
Limestone	8.50
Calcium hydrogen phosphate (CaHPO)	1.60
Wheat middlings	3.00
Soybean oil	0.50
Choline chloride	0.10
Methionine (Met)	0.12
Lysine (Lys)	0.03
Threonine (Thr)	0.05
Premix[1]	1.00
Total	**100.00**
Nutrient levels[2]	
Metabolizable energy (ME) / (MJ/kg)	11.30
Crude protein (CP)	16.50
Available phosphorus (AP)	0.35
Lysine	0.78
Threonine	0.58
Methionine	0.38
Zinc / (mg/kg)	38.29
Manganese / (mg/kg)	28.72

[1] The premix provided the following per kg of diet: VA 8,000 IU, VD 750 IU, VE 100 mg, VK 3 mg, VB 12.5 mg, VB 9 mg, VB 0.03 mg, pantothenic acid

18 mg, niacin 60 mg, folic acid 1.5 mg, biotin 0.225 mg, Fe 80 mg, Cu 9 mg, I 0.9 mg, Se 0.3 mg, Mn 12.55 mg, Zn 25.2 mg.

[2] Nutrient levels were all calculated values.

1.3 Feeding Management

The experiment was conducted in a fully enclosed chicken house with artificial lighting of 15 h/d at 20 lx intensity, relative humidity of 65-80%, and temperature of 20-24°C. Hens were fed twice daily with ad libitum access to feed and water. Eggs were collected daily by replicate.

1.4.1 Production Performance

Body weight was measured individually at the end of weeks 1, 8, 16, 24, and 32. Eggs were collected daily, and egg weight, number of eggs, and number of broken eggs were recorded by replicate to calculate average egg weight, laying rate, and broken egg rate. Eggs produced during weeks 16 and 32 were incubated, and fertility, hatchability of fertile eggs, and livability were recorded by replicate.

Fertility (%) = (Number of fertile eggs / Number of incubated eggs) × 100
Hatchability of fertile eggs (%) = (Number of chicks hatched / Number of fertile eggs) × 100
Livability rate (%) = (Number of healthy chicks / Number of chicks hatched) × 100

1.4.2 Egg Quality

At weeks 16 and 32, 3 eggs per replicate were randomly selected to determine eggshell strength, egg shape index, eggshell thickness, albumen height, Haugh unit, eggshell color, and yolk ratio. Eggshell strength was measured using an eggshell force gauge (Model-III, Robotmation, Japan). Eggshell thickness was measured using an eggshell thickness gauge (Model P-1, Ozaki MFG, Japan). Albumen height and Haugh unit were measured using an egg quality tester (EMT-2500, Robotmation, Japan). Eggshell color was measured using a CR-10 colorimeter at three points (large end, middle, and small end) to determine lightness (L*), redness (a*), and yellowness (b*) values, which were averaged. Egg shape index was calculated as:

Egg shape index (%) = (Longitudinal diameter / Transverse diameter) × 100

At weeks 16 and 32, 5 eggs per replicate were randomly selected. After cooking, yolks from the same replicate were pooled and zinc and manganese contents were determined by flame atomic absorption spectrophotometry.

1.4.3 Blood Antioxidant and Immune Indices

At the end of week 32, 2 hens per replicate were randomly selected for blood collection from the wing vein. Activities of antioxidant enzymes [manganese superoxide dismutase (Mn-SOD) and copper-zinc superoxide dismutase (Cu/Zn-SOD)] and T lymphocyte subsets (CD4, CD8) were measured. Mn-SOD and Cu/Zn-SOD activities were determined using a Biyuntian CuZn/Mn-SOD activity assay kit (WST-8 method). T lymphocyte subset proportions were detected by flow cytometry, and Cell Quest software was used to analyze the percentages of CD4 and CD8 T lymphocytes in peripheral blood T lymphocytes. At the end of weeks 31 and 32, 2 hens per replicate were randomly selected, and wattle thickness was measured with a vernier caliper before and 24 h after injection with phytohemagglutinin (L8754, Sigma-Aldrich, USA). The percentage change was calculated as a measure of cutaneous basophil hypersensitivity (CBA) reaction.

1.5 Data Processing and Analysis

Data were analyzed using one-way ANOVA procedure in SAS 9.13 software. Duncan' s multiple range test was used for post-hoc comparisons. Results are expressed as "mean ± standard error." $P<0.01$ indicated extremely significant difference, $P<0.05$ indicated significant difference, and 0.05 $P<0.10$ indicated a significant trend.

2.1 Effects of Organic Zinc and Manganese on Production Performance of Laying Breeder Hens

As shown in Table 2 , dietary organic zinc and manganese had no significant effects on body weight or body weight gain of laying breeder hens compared with the control group ($P>0.05$).

Table 2 Effects of organic zinc and manganese on growth performance of laying breeder hens

Item	Trial week	Control (A)	Group B	Group C	P-value
Body weight (kg)	17-24	1.67±0.02	1.69±0.01	1.67±0.01	0.67
	25-32	1.80±0.02	1.84±0.02	1.81±0.02	0.41
	1-8	1.85±0.03	1.89±0.02	1.85±0.02	0.52
	8-16	1.88±0.03	1.94±0.03	1.88±0.02	0.28
	16-24	1.92±0.03	1.97±0.03	1.92±0.03	0.46
Body weight gain (kg)	24-32	0.14±0.02	0.15±0.02	0.14±0.02	0.91
	1-32	0.18±0.02	0.20±0.02	0.18±0.02	0.74
		0.22±0.02	0.25±0.03	0.21±0.03	0.55
		0.26±0.03	0.28±0.03	0.25±0.03	0.79

In the same row, values with the same or no letter superscripts mean no significant difference ($P>0.05$), while different small letter superscripts indicate significant difference ($P<0.05$), and different capital letter superscripts indicate extremely significant difference ($P<0.01$). The same applies below.

As shown in Table 3 , at week 32, average egg weight in Group B was significantly higher than in the control and Group C ($P<0.05$). During weeks 1-32, average egg weight in Group B was significantly higher than in the control group ($P<0.05$) but did not differ significantly from Group C ($P>0.05$). At week 24, laying rate in Group C was significantly higher than in the control group ($P<0.05$) but did not differ significantly from Group B ($P>0.05$). Broken egg rate in Group C was significantly lower than in Group B ($P<0.05$) and extremely significantly lower than in the control group ($P<0.01$), while no significant difference was observed between Group B and the control group ($P>0.05$).

Table 3 Effects of organic zinc and manganese on laying performance of laying breeder hens

Item	Trial week	Control (A)	Group B	Group C	P-value
Average egg weight (g)	1-8	57.95±0.23	58.28±0.27	57.95±0.23	0.65
	8-16	58.58±0.31	60.86±0.29	58.58±0.31	0.65
	16-24	58.28±0.27	60.17±0.45	58.28±0.27	0.65
	24-32	60.44±0.27	61.46±0.45	60.44±0.27	0.65
	1-32	60.55±0.40b	62.14±0.55a	60.78±0.31b	0.04
Laying rate (%)	1-8	95.58±0.69	96.24±1.15	95.58±0.69	0.82
	8-16	95.93±0.67	95.97±0.98	95.93±0.67	0.82
	16-24	96.24±1.15	95.97±0.98	96.24±1.15	0.82
	24-32	88.92±1.17b	92.94±1.28a	92.94±1.28a	0.04
	1-32	90.86±0.48	92.23±0.63	92.23±0.63	0.15
Broken egg rate (%)		1.06±0.16Aa	0.91±0.12ABa	0.49±0.09Bb	<0.01

As shown in Table 4 , compared with the control group, dietary organic zinc and manganese had no significant effects on fertility, hatchability of fertile eggs, or livability rate at weeks 16 and 32 ($P>0.05$).

Table 4 Effects of organic zinc and manganese on reproductive performance of laying breeder hens

Item	Trial week	Control (A)	Group B	Group C	P-value
Fertility (%)	16	94.25±0.70	94.44±0.89	94.25±0.70	0.94
	32	90.31±1.03	90.71±0.65	90.31±1.03	0.83
Hatchability of fertile eggs (%)	16	83.53±1.56	83.13±1.54	83.53±1.56	0.89
	32	73.85±2.63	76.25±0.87	73.85±2.63	0.45
Livability rate (%)	16	91.90±0.58	91.42±1.08	91.90±0.58	0.79
	32	85.19±1.10	86.88±0.63	85.19±1.10	0.31

2.2 Effects of Organic Zinc and Manganese on Egg Quality of Laying Breeder Hens

As shown in Table 5 , at week 16, egg shape index in Group B was significantly higher than in the control and Group C ($P<0.05$). At week 32, eggshell lightness in Group C was significantly higher than in Group B ($P<0.05$), while eggshell redness in Groups B and C was extremely significantly higher than in the control group ($P<0.01$). No significant differences were observed among groups in eggshell strength, eggshell thickness, relative albumen height, Haugh unit, eggshell yellowness, or yolk ratio ($P>0.05$).

Table 5 Effects of organic zinc and manganese on egg quality of laying breeder hens

Item	Trial week	Control (A)	Group B	Group C	P-value
Eggshell strength (kg・f)	16	4.53±0.10	4.43±0.09	4.53±0.10	0.65
	32	4.71±0.06	3.61±0.11	4.71±0.06	0.65
Egg shape index	16	3.75±0.19b	3.51±0.13b	3.75±0.19b	0.04
	32	1.26±0.01b	1.33±0.01	1.26±0.01b	0.04
Eggshell thickness (mm)	16	1.28±0.01a	1.32±0.01	1.28±0.01a	0.04

Item	Trial week	Control (A)	Group B	Group C	P-value
	32	1.26±0.01b	1.31±0.01	1.26±0.01b	0.04
Relative albumen height (%)	16	32.77±0.64	33.56±0.49	32.77±0.64	0.65
	32	32.17±0.60	32.39±0.55	32.17±0.60	0.65
Haugh unit	16	9.83±0.28	10.07±0.31	9.83±0.28	0.65
	32	10.77±0.32	6.81±0.34	10.77±0.32	0.65
Lightness (L*)	16	77.11±1.07	77.27±1.46	77.11±1.07	0.65
	32	80.44±1.14ab	62.73±2.57b	80.44±1.14ab	0.04
Redness (a*)	16	56.66±0.49	55.92±0.39	56.66±0.49	0.65
	32	55.88±0.51b	55.12±0.64a	55.88±0.51b	<0.01
Yellowness (b*)	16	14.02±0.18	14.47±0.17	14.02±0.18	0.65
	32	14.32±0.22Aa	14.37±0.20Aa	14.32±0.22Aa	<0.01
Yolk ratio (%)	16	29.47±0.26	29.02±0.43	29.47±0.26	0.65
	32	29.10±0.20	29.04±0.27	29.10±0.20	0.65

As shown in Table 6 , at week 16, yolk manganese content in Group C was significantly higher than in the control group (P<0.05), with no significant difference between Groups B and C (P>0.05). At week 32, yolk manganese content in Group B was extremely significantly higher than in the control and Group C (P<0.01). No significant differences were observed among groups in yolk zinc content (P>0.05).

Table 6 Effects of organic zinc and manganese on zinc and manganese contents in egg yolk of laying breeder hens (mg/kg)

Item	Trial week	Control (A)	Group B	Group C	P-value
Zinc	16	94.61±2.02	94.85±1.99	94.61±2.02	0.96
	32	117.55±3.75	111.59±2.63	117.55±3.75	0.28
Manganese	16	4.54±0.11b	4.84±0.05a	4.84±0.05a	0.04
	32	4.22±0.09Bb	4.66±0.11Aa	4.06±0.10Bc	<0.01

2.3 Effects of Organic Zinc and Manganese on Blood Antioxidant Indices of Laying Breeder Hens

As shown in Table 7 , dietary organic zinc and manganese had no significant effects on blood total superoxide dismutase (T-SOD), Mn-SOD, or Cu/Zn-SOD activities compared with the control group (P>0.05).

Table 7 Effects of organic zinc and manganese on blood antioxidant indices of laying breeder hens

Item	Control (A)	Group B	Group C	P-value
T-SOD	4.43±0.50	4.68±0.63	4.43±0.50	0.87
Mn-SOD	0.42±0.05	0.34±0.02	0.42±0.05	0.28
Cu/Zn-SOD	4.02±0.52	4.34±0.65	4.02±0.52	0.87

2.4 Effects of Organic Zinc and Manganese on Cellular Immune Function of Laying Breeder Hens

As shown in Table 8 , dietary organic zinc and manganese had no significant effects on blood T lymphocyte subset proportions (CD4, CD8, and CD4/CD8 ratio) or CBH reaction compared with the control group (P>0.05).

Table 8 Effects of organic zinc and manganese on blood T lymphocyte subset proportions and CBH reaction of laying breeder hens

Item	Control (A)	Group B	Group C	P-value
T lymphocyte subset proportion				
CD4 (%)	7.56±0.67	8.68±0.85	7.56±0.67	0.55
CD8 (%)	1.06±0.15	1.36±0.20	1.06±0.15	0.34
CD4/CD8	8.20±1.30	7.27±1.10	8.20±1.30	0.74
CBH reaction				
Week 31	0.68±0.06	0.81±0.09	0.68±0.06	0.40
Week 32	0.71±0.08	0.82±0.06	0.71±0.08	0.47

3.1 Effects of Dietary Organic Zinc and Manganese on Production Performance of Laying Breeder Hens

Zinc and manganese are important trace elements that participate in the synthesis and metabolism of various essential substances and are required for growth and development. Research has shown that dietary supplementation with 60 and 90 mg/kg organic manganese significantly reduced feed-to-gain ratio and showed a trend toward increased average daily gain in 3-week-old broilers. Other studies have reported no significant effects of different manganese sources on feed intake or feed-to-gain ratio in broiler chicks. In this experiment, body weight and weight gain in the equivalent replacement group were increased compared with the control group, but the differences were not significant, which is consistent with previous research.

Cheng Tingshui et al. reported that dietary supplementation with amino acid-complexed zinc, copper, and manganese significantly improved laying rate and egg production compared with equivalent doses of sulfate forms. In this study, dietary organic zinc and manganese increased average egg weight and laying rate, consistent with previous findings. Compared with the control group, the extra supplementation group showed an extremely significant reduction in broken egg rate, indicating that organic zinc and manganese supplementation improved eggshell quality and reduced breakage. Trace elements may affect eggshell quality by influencing key enzymes involved in eggshell and shell membrane formation or by directly affecting calcium crystal structure formation.

3.2 Effects of Dietary Organic Zinc and Manganese on Egg Quality of Laying Breeder Hens

Yuan Jianmin et al. reported that dietary supplementation with different concentrations of zinc and manganese had no significant effect on eggshell color. However, in this experiment, dietary organic zinc and manganese significantly altered eggshell lightness and redness at week 32, while eggshell strength, thickness, relative albumen height, Haugh unit, yellowness, and yolk ratio remained unchanged. Sun Qiujuan et al. demonstrated that methionine-chelated trace elements promoted deposition in eggs compared with inorganic forms. In this study, dietary organic zinc and manganese significantly increased yolk manganese content compared with inorganic forms, while yolk zinc content was unaffected, suggesting that organic manganese is more readily absorbed and deposited in egg yolk.

3.3 Effects of Dietary Organic Zinc and Manganese on Antioxidant Capacity of Laying Breeder Hens

Superoxide dismutase (SOD) effectively scavenges oxygen free radicals, blocks production of toxic hydroxide ions, and protects cells from damage. Eukaryotic cells contain two SOD types: Mn-SOD and Cu/Zn-SOD. Dietary supplementation with different zinc forms can increase serum Cu/Zn-SOD activity, with organic zinc showing superior effects to inorganic zinc. In this experiment, dietary organic zinc and manganese had no significant effects on blood Mn-SOD and Cu/Zn-SOD activities, suggesting that the supplementation levels were insufficient to significantly affect antioxidant capacity. This discrepancy may be attributed to differences in zinc and manganese supplementation levels and physiological variations among experimental animals.

3.4 Effects of Dietary Organic Zinc and Manganese on Immune Function of Laying Breeder Hens

This study evaluated cellular immune function by measuring T lymphocyte subset proportions and CBH reaction. Research indicates that zinc deficiency reduces cellular immune function, decreasing peripheral blood CD4, CD8, and CD4/CD8 ratio, with CD4 showing the most pronounced reduction, which normalizes after zinc supplementation. In this experiment, dietary organic zinc and manganese did not significantly alter CD4, CD8, or CD4/CD8 ratio, although CD4 proportion showed the greatest increase, similar to previous studies. Dietary organic zinc and manganese had no significant effect on CBH reaction, though equivalent replacement tended to increase CBH response. Studies have shown that dietary amino acid zinc significantly increased CBH reaction in laying hens compared with the control group, and organic zinc, copper, and manganese supplementation produced significantly higher CBH reactions than inorganic forms.

Inorganic trace elements are subject to various interfering factors in animals, including reactions with lipids, proteins, fiber, oxalic acid, oxides, and vitamins, as well as interactions with other minerals, phosphates, and phytates. Amino acid-chelated trace elements have high bioavailability, no compatibility issues with vitamins or antibiotics, and a structure similar to natural enzyme forms, facilitating incorporation into body components after absorption and thereby enhancing immune function and disease resistance.

4 Conclusion

Dietary supplementation with organic zinc and organic manganese can increase average egg weight and laying rate, decrease broken egg rate, improve eggshell strength and egg quality, and increase manganese deposition in egg yolk of laying breeder hens. Under the conditions of this experiment, equivalent replacement of inorganic zinc and manganese with organic forms produced the optimal effects.

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